

NAS Miramar Molten Carbonate Fuel Cell Demonstration Status

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Introduction

There is a need to demonstrate Molten Carbonate Fuel Cell (MCFC) power plant systems in order to establish a cost and performance track record for the emerging MCFC technology. It is intended that the MCFC demonstration power plant would provide a configuration which supports the demonstration of a M-C Power internally manifolded (IMHEX[®]) 250 kW MCFC stack. The demonstration provides an ideal vehicle for developing utility and other end-user support for the technology which would provide the confidence necessary to encourage the purchase of MCFC power plants. The demonstration incorporates full-scale and full-height stack and balance of plant (BOP) system testing. Testing goals are consistent with M-C Power's commercialization plan and with product definition requirements identified through extensive market research. The target capacity range for commercial plants is from 250 kW to 1 MW and higher which makes the power plant size well suited for a wide range of on-site and distributed power applications that are expected to grow in importance over the coming decade.

Objective

The objective of this Cooperative Agreement is to support the Product Development Test (PDT) of an M-C Power full-area, full-height 250 kW MCFC stack in order to accelerate commercialization of the technology. Another objective is to demonstrate the M-C Power team's capability to design, manufacture, assemble and test MCFC power plants which are close to a commercial configuration. By definition, the 250 kW NAS Miramar molten carbonate fuel cell demonstration is an integrated power plant which is consistent with M-C Power's commercial development plan.

Approach

The project has been developed in accordance with DOE guidelines under the Cooperative Agreement established between M-C Power and the DOE. DOE funded the design, manufacturing and fabrication of the 250 kW stack which consisted of 250 cells with an active area of 10,800 cm² per cell. All costs associated with the necessary BOP were funded by the Gas

Research Institute (GRI). Funds for testing of the demonstration power plant were provided under tailored collaboration with the Electric Power Research Institute (EPRI). The DOD's Advanced Research Projects Agency (ARPA) has funded the site relocation to Miramar and a 20 kW stack test. Additional funding was supplied by Bechtel Corporation, Pennsylvania Power & Light, San Diego Gas & Electric (SDG&E), Southern California Gas (SoCalGas), Stewart & Stevenson Services, Inc. (S&S) and Sydkraft AB of Sweden.

M-C Power managed the project. Bechtel was responsible for the design, detailed engineering, construction management and plant start-up. S&S fabricated the balance of plant (BOP) in their shop on a skid and tested the performance prior to shipping to the site. SDG&E performed site construction work with its own staff which was supplemented by craft labor under subcontracts with them. The project was executed over the period September 30, 1992 through March 31, 1997. M-C Power operated the plant with its own funding and utility support 2 ½ months beyond the March 31, 1997 Cooperative Agreement end date.

Project Description

The project includes the design, procurement, construction, start-up and operation of the world's first 250 kW cogeneration MCFC power plant. The demonstration plant is designed to produce 250 kW net of electricity as well as 340 - 640 pounds per hour of 100 psig steam for use in NAS Miramar's district heating system. It is located on the NAS Miramar military base which is about 15 miles northeast of downtown San Diego. The plant, occupying a 40 x 80 square foot area, has three main components: a fuel processor (reformer), a BOP skid and the fuel cell stack. Auxiliary equipment includes a nitrogen storage tank and vaporizer, and a boiler feed water make-up system which are separate from the BOP skid. In the market entry plant, this auxiliary equipment will be either eliminated or included within the BOP skid. The electrical equipment and control system are located in a separate building. The electrical and control systems are being reduced to cabinet size in the market entry design.

Results

Construction Schedule

Site preparation and civil construction were completed in November 1995 which was six months after the construction start date. The stack was shipped to the site in August of 1996. The plant was mechanically complete the following month and electrical acceptance took place on October 15, 1996 as shown in Figure 1 (NAS Miramar Operating Schedule). Process and Control (PAC) testing started in September 1996 and was completed in December.

Fuel Cell Stack

Between April and July 1996 the final assembly, conditioning and acceptance testing of the stack took place. The stack was conditioned in the Acceptance Test Facility (ATF) and tested at 400 to 425 amps load. Conditioning and testing lasted a total of 593 operating hours. Binder removal was conducted for approximately 247 hours. Electrolyte melting was completed in 162

hours. Throughout the electrolyte melting, the gas manifold pressures remained positive indicating excellent sealing. Cathode oxidation was completed in 39 hours.

Acceptance Testing

During acceptance testing the stack generated power for 210 hours. The maximum load current obtained during this testing was 546 amps with the maximum power output of 107 kW. The stack operated at a steady state load of approximately 400 amps for 164 hours with the output power of 90 kW. During operation the stack met the stated acceptance criteria: > 207.5 VDC at 40 mA/cm². No apparent cell package voltage decay was observed during operation. Final stack cooling after acceptance testing was completed in 160 hours. Ambient temperature crossover testing before and after stack conditioning met the acceptance criteria of less than 0.4 slpm/cell gas leakage at a stack clamping force of 40 psi and differential pressure of 10" WC.

Plant Performance

The demonstration project first produced power on January 24, 1997. In addition to an impressive list of technology successes and the verification of key operating systems, the power plant produced 158 megawatt hours of electricity and 296,000 pounds of steam. This was the first time any molten carbonate fuel cell power plant has been used for cogeneration, providing both electricity and high quality steam in a utility grid application. The quality of electricity and steam produced was excellent. Transitions between being on and off-line were smooth. These transitions were completely unnoticeable to power and steam users in the local NAS Miramar systems.

Figure 2 (NAS Miramar 250-kW Stack - Stack DC Cumulative Power) presents the electricity production history of the demonstration plant. The slow initial power production during the first 900 hours corresponds to the time when instrumentation electrical interference issues were being resolved. At this time the inverter was taken off line. Between 900 hours and 1900 hours of operation took place utilizing a load device. At 1250, 1450 and 1650 hours the stack exhibited off load operation due to malfunction of rotating equipment. At approximately 1900 hours through 2300 hours the inverter was operational when rotating equipment again malfunctioned.

Figure 3 (NAS Miramar Stack Performance - OCV) shows excellent cell to cell uniformity. The average voltage is shown in the left bar. There is excellent correlation between the OCV's in the demonstration stack and with small-height scale tests in the laboratory even with the scale up factor of 12.5 times. Bench scale tests were run in parallel for diagnostic purposes.

Figure 4 (NAS Miramar Stack Performance - 1140 ADC, 206 kW) shows excellent voltage distribution. This uniformity is at 66% of design load and at actual power plant conditions (low CO₂/O₂) concentration. The upward trend is due to temperature gradient from the bottom to the top of the stack. Voltage uniformity also indicates an above average gas distribution demonstrating that hydrodynamic design is under control.

Figure 5 (250 kW Miramar Stack Actual versus Predicted Performance) is a voltage comparison between the electrochemical model predictions and actual voltage performance. The difference between predictions and actual performance achieved is less than 8%. Even though results are extremely good, further enhancements of the model to predict low oxidant conditions are under development.

There was superior stack voltage distribution throughout the stack and once again confirmed no evidence of electrolyte movement. All internal seals held over a wide range of test pressures which verified that they would hold under adverse operating conditions. The plant easily moved between standby and on-load operations without the use of supplemental CO₂.

The DOE Cooperative Agreement ended on March 31, 1997, but M-C Power chose to operate the plant for an additional 2 ½ months. With limited additional funds, the decision was made to shut down the plant. The stack was removed and transported to M-C Power's manufacturing and testing facilities where it will be analyzed.

The demonstration project met its test objective by:

- Demonstrating major equipment/system performance in an actual end-user application using commercial operating parameters and fuel conditions.
- Proving that the technology can operate in a distributed generation mode.
- Confirmed that the plant can start up and operate with standard electric utility operating personnel.
- Proved that there is no electrolyte migration in the stack.

There are some enhancements to the BOP and stack which will move the technology closer to commercialization. On the BOP side these improvements include better performance from the hot gas blower and turbocharger. New and improved equipment are ready for installation and testing. In future operations, stack performance will be improved by a new plate design which will incorporate 310 SS instead of 316 SS for better corrosion resistance.

Application

Plant startup and operating experience has amply demonstrated that M-C Power's MCFC stack can be integrated effectively into a power plant configuration. The stack design has shown impressive stability and resiliency under adverse operating conditions as has the new reformer. Design and operating experience is already being used to further improve the reliability and operability of the next generation of power plants which are currently being designed. Plant operating experience has revealed that BOP equipment specifications should be relaxed to provide improved power plant operating flexibility. Major equipment and systems performance has shown that simpler and cheaper designs are possible for the market entry power plants. An elaborate instrumentation and control system at NAS Miramar has provided data which will further

contribute to simple and reliable commercial designs. The demonstration has also proven that commercial cost targets are achievable.

Future Activities

The NAS Miramar Demonstration Plant is currently in a standby mode of operation. Plans are being developed to use the power plant as a test facility for MCFC stacks which incorporate advanced components. These components, already proven in the laboratory, will be included in the early market entry power plants. The Miramar plant will also be used to test improved BOP equipment and control systems which meet commercial operating specifications and cost goals.

Acknowledgments

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The Molten Carbonate Fuel Cell (MCFC) Product Development Test project is a Cooperative Agreement (DE-FC21-92MC28065) between the U.S. Department of Energy and M-C Power Corporation, 8040 S. Madison Street, Burr Ridge, IL 60521; phone (630) 986-8040; fax (630) 986-8153. The project was administered by the Federal Energy Technology Center (FETC). Dr. Diane Traub Hooie is the FETC Contracting Officer's Representative (COR). The project was executed over the period September 30, 1992 through March 31, 1997. Subcontractors included San Diego Gas & Electric and Bechtel Corporation. The Institute of Gas Technology (IGT) and Stewart & Stevenson Services, Inc. (S&S) performed work under a Gas Research Institute (GRI) subcontract which was cost shared into the project. Under the Cooperative Agreement with DOE. The U.S. Advanced Research Projects Agency (ARPA) provided financial assistance.

Figure 1

NAS Miramar Operating Schedule

		Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Mechanical Completion									
Plant Start Up									
PAC Test									
F. C. Integration									
F.C. Heat up									
F.C. Operation									

Fig. 2 NAS Miramar 250-kW Stack

Stack DC Cumulative Power

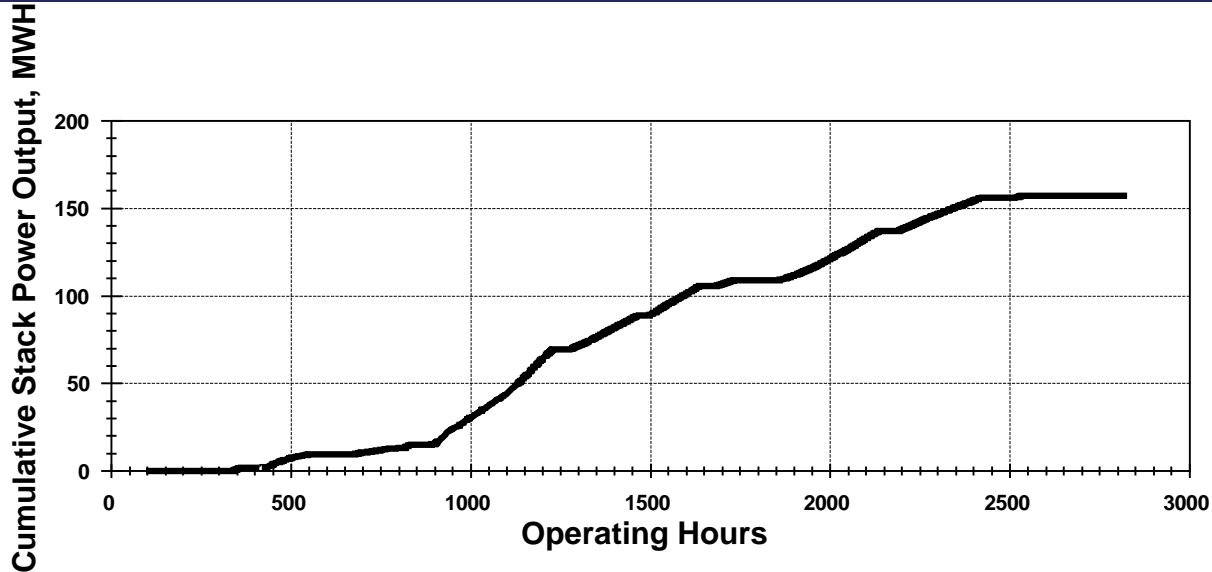


Fig. 3 NAS Miramar Stack Performance - OCV

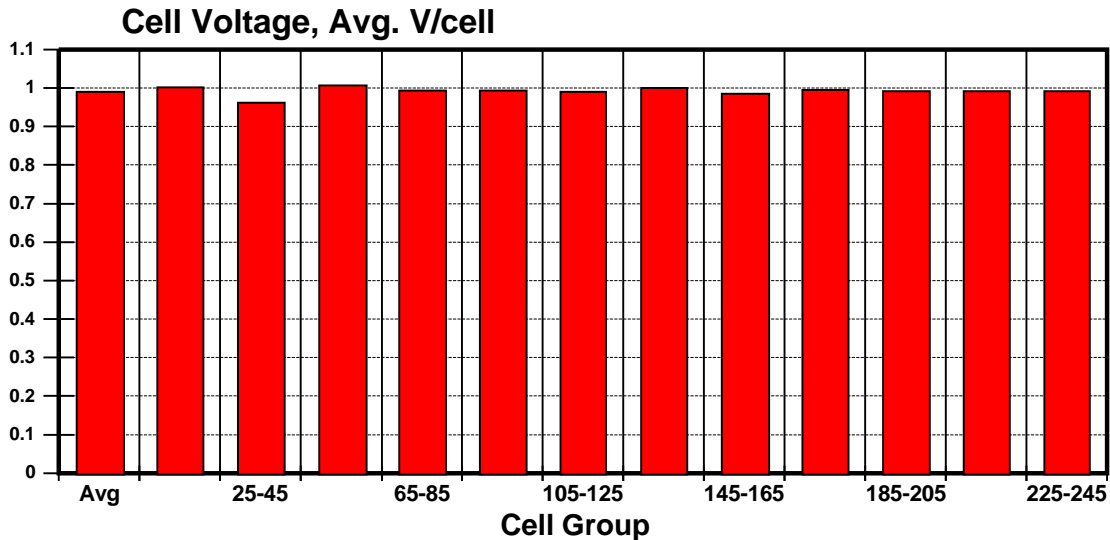


Fig. 4 NAS Miramar Stack Performance-- 1140 ADC, 206 kW

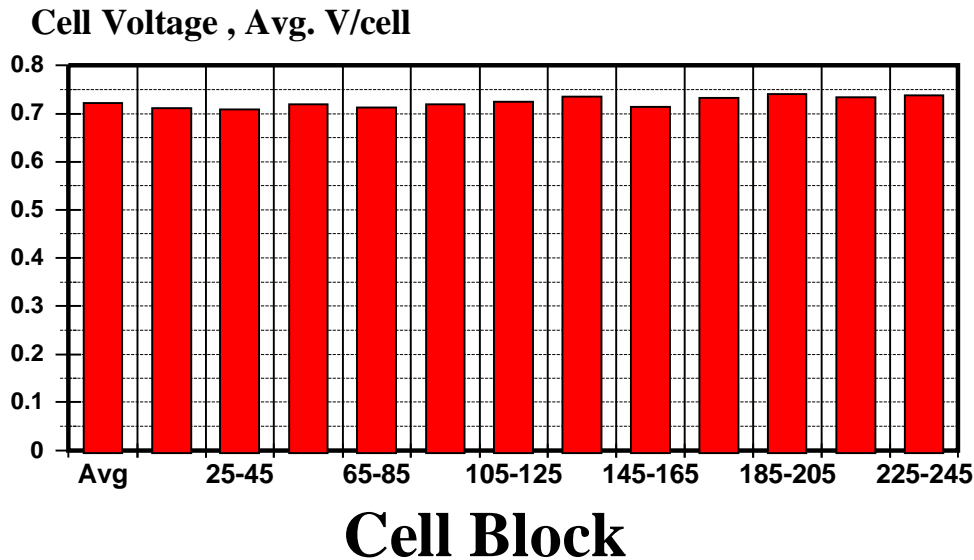


Fig. 5 250 kW Miramar Stack

